MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 3, 2018/2019

ENT4066 – NANOELECTRONICS MATERIALS AND DEVICES
(NE)

31 MAY 2019
9.00 a.m. – 11.00 a.m.
(2 Hours)

INSTRUCTION TO STUDENTS

1. This examination paper consists of 5 pages with 4 questions only.

2. Attempt **ALL FOUR** questions. All questions carry equal marks and the distribution of the marks for each question is given.

3. Please print all your answers in the Answer Booklet provided.

QUESTION 1

(a) (i) Provide the definition for each of the terms in **Table Q1(a)** below:

Table Q1(a)

Term	Definition
Cluster	
Fullerenes	
Quantum dot	
Carbon nanotubes	

[4 marks]

(ii) Briefly explain the phenomenon termed as "Quantum Confinement" in nanocrystal.

[2 marks]

(iii) Why the melting point of the nanometer order materials decrease from that of the bulk materials? Probe the above statement considering an example for Gold nanoparticles compare with a bulk particle of Gold.

[4 marks]

(b) (i) Energy bandgap of nanoparticle change with the change in the particle size. Briefly explain how the energy bandgap of nanoparticle differs from that of the bulk.

[4 marks]

(ii) What are the differences of "Exciton Bohr Radius" for a large semiconductor crystal and that of a quantum dot nanomaterial?

[3 marks]

(c) (i) Explain the relation between the "energy barrier" that a nucleation process must overcome with the "critical size" of a homogenously nucleated nanoparticles.

[3 marks]

(ii) With the aid of suitable diagram explain the process of nucleation and subsequent growth, specify when the nucleation occurs.

[5 marks]

Continued.....

QUESTION 2

(a) Briefly explain **THREE (3)** advantages and disadvantages of solid state reaction on top-down processing of Nanoparticles.

[3 marks]

(b) What is the physical phenomenon behind the optical emission of a surface plasmonic effect.

[3 marks]

(c) Consider (15, 6) is a single-wall carbon nanotubes (SWCNT). If chiral angle (θ) and diameter (d) of a carbon nanotube (CNT) is given by:

$$\theta = tan^{-1}\left[\frac{\sqrt{3}\,m}{m+2n}\right]$$

$$d = \frac{\sqrt{3}\,a_{cc}\sqrt{(m^2+n^2+mn)}}{\pi}$$

respectively, where m and n are integers governing the chiral vector C, and a_{cc} = 0.142 nm is the carbon bond length. If unzipping the SWCNT form a 10-μm Graphene sheet,

(c. i) Calculate the chiral angle and diameter of the SWCNT. [4 marks]

(c. ii) Is this a metallic or semiconductor type of CNT? [1 mark]

(d) List **TWO (2)** mechanical properties of CNT and provide an example of CNT application that utilized the mechanical properties. [5 marks]

(e) **Figure Q2(e)** shows Density-of-states D(E) with Van- Hove singularities for (3,3), (5,5) and (10,10) armchair nanowire with N=3,600 number of the atoms. Explain "Van Hove Singularities" based on the **Figure Q2(e)**.

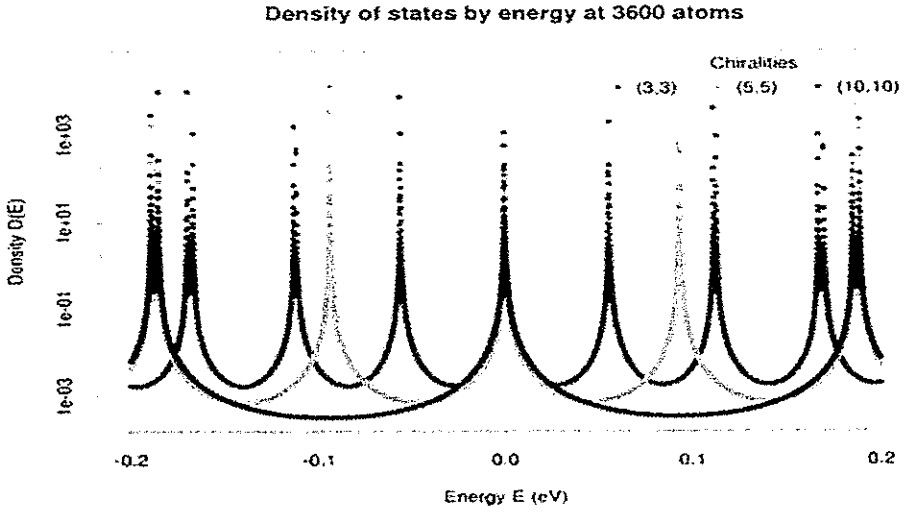

Figure Q2(e)

[5 marks]

(f) With the aid of a diagram, explain the influence of time on the growth of monodispersed colloid.

[4 marks]

Continued.....

QUESTION 3

(a) Differentiate the three scaling rules; *constant field scaling*, *generalized scaling* and *generalized selective scaling*, of metal-oxide-semiconductor field-effect transistor (MOSFET). Explain the significance of such scaling rules.

[4 marks]

(b) Chemical vapour deposition (CVD) is a particular method to deposit Graphene on metal. With the aid of diagram, write a short note about CVD deposition of Graphene on metal.

[6 marks]

(c) (i) Single-electron transistor (SET) is consider as a state of the art nanoelectronic device where a quantum dot is weakly coupled between two thin metallic drain and source. Briefly sketch the equivalent circuit of a SET device. [2 marks]

(ii) What are the **TWO (2)** important criteria govern the SET operation. [2 marks]

(iii) Derive that the threshold V_{th} is given by e/C_{tot}, where C_{tot} is the total capacitance.

[3 marks]

(d) (i) What are the **THREE** (3) variant of Silicon on Insulator (SOI) devices? Compare their strengths and weaknesses.

[3 marks]

(ii) In the device fabrication SOI is often depleted partially. However, during the depletion process floating body effects (FBE) is not desirable, explain why FBE is not desirable during depletion process?

[3 marks]

(e) What would be the scaling limitation of very thin SiO_2 if chip manufacturers shrunken the thickness of the dielectric to as little as five atomic layers (1.2 nm)?

[2 marks]

Continued.....

QUESTION 4

(a) (i) Among quantum effect devices, what are the superior characteristics of "Resonant Tunnelling Diodes (RTDs)" based device.

[2 marks]

(ii) With the aid of a diagram, explain Peak(p)-to-Valley(v) Ratio of a RTD device.

[2 marks]

(iii) In a single-electron device, if capacitance can be quantify by the equation $C=2\pi\varepsilon\varepsilon_o d$, where d (60 nm) is the diameter of island, $\varepsilon=4$ and $\varepsilon_o = 8.89\text{x}10^{-12}$ F/m. Calculate the temperature limit for SET effect. Given that Boltzmann's constant is $1.38066\text{x}10^{-23}$ J/K.

[3 marks]

(b) Single electron transistor (SET) devices are expected to bring a revolution in the electronic devices. With the aid of a diagram illustrate the different regime of a SET devices and explain the operational principles of the SET devices.

[5 marks]

(c) Describe the working principle of the SET devices if they are used in the following applications:
(i) Single electron memory
(ii) High sensitivity electrometer
(iii) Microwave detection

[3 marks]

(d) What are the main components and popular geometry of an organic field-effect transistors (OFETs). Explain how OFET can contribute to low cost electronic circuits development.

[5 marks]

(e) Explain the "Separation by Implantation of Oxygen (SIMOX)" process to fabricate a buried SiO_2 layer used in nanoelectronic devices.

[5 marks]

End of Paper.